

SCIENCE OPPORTUNITIES BY MID-IR OBSERVATIONS FROM A SOFIA UPPER DECK RESEARCH FACILITY

Ray W. Russell¹

¹*The Aerospace Corporation, M2-266, P.O. Box 92957, Los Angeles, CA, 90009-2957 USA*

ABSTRACT

The Stratospheric Observatory for Infrared Astronomy (SOFIA), an airborne infrared and submm observatory on a B747, will provide many observing opportunities over each year of its projected 20 year lifetime. This means that time dependent and/or spatially extended phenomena may be viable candidates for study from its upper deck. This paper takes a qualitative overview of some of the studies that might benefit from using those flights.

INTRODUCTION

SOFIA is the Stratospheric Observatory for Infrared Astronomy - a world-class astronomical observatory for infrared and submm astronomy that follows the tradition of the NASA LearJet Observatory and Kuiper Airborne Observatory (KAO). Both of these predecessors were very productive facilities that exploited developing IR technology and made significant astronomical discoveries, including numerous far-IR forbidden lines that can be used for nebular abundance analyses and determination of source properties such as temperature and density, as well as properties of interstellar dust that are still being investigated today. Serendipitously, other experiments were operated on the KAO, such as Pete Kuhn's water vapor radiometer. Kuhn flew on many flights, collecting data that related clear air turbulence with water vapor emission, while providing the valuable service to the main observing teams of the water content in the air above the plane to aid them in analyzing their scientific data. In fact, that successful tool led to the currently planned facility water vapor radiometer that will be mounted on the upper deck. With this paradigm, and the experiences of Dr. Jenniskens and his Leonid Multi-Instrument Aircraft Campaign (Leonid MAC) study teams that have flown four successful airborne meteor study missions in the past few years, we can consider the opportunities that the upper deck on SOFIA could offer.

SCIENCE STUDIES –ASTRONOMICAL

One of the results of the LearJet Observatory Program was the recognition of the value of a small telescope that could point close to the horizon. The windows of the SOFIA upper deck afford a view from 0-68 degrees in elevation, and the placement of multiple windows would afford access to different azimuths, in addition to the natural variation in azimuth as the plane follows the prescribed flight plan for the science being done on the main telescope. A small telescope can look at larger portions of the sky, and this is ideally suited to the study of the entire coma of an extended comet. While not all wavelengths would be accessible to a sensor that is not open port, many would be, and the high altitude and low

extinction vs airmass would make this a very appealing platform from which to study comets. The large number of flights would allow for temporal studies of comets, and in view of the recent dynamic pictures being sent back from the STARDUST mission, this would be a potentially valuable area of study. We would like to know how homogeneous the surfaces of these comets are, and studying their emissions in the 3.5, 10, and 20 micron windows (with a modest cooled nitrogen purge, as done on the government's HALO aircraft, for example) would allow an in-depth study of this question.

Similarly, there are many bright stars that could bear further investigation. Many late-type stars have water vapor features that could be studied with a modest telescope and spectrograph (much like the MIRIS sensor that Rossano has flown successfully on the Leonid MAC flights) and a purged connection to a window. Some modest pointing capability, such as the steering mirrors that were flown on the Convair 990 and LJO in the past, would be required, but again, all of this is within the realm of feasible study, having been already demonstrated on previous missions. Strecker did a study of variable stars using the LJO for much of his work, and with the newer technology available today, this work could be greatly expanded from the upper deck of SOFIA.

Several other papers will be addressing the potential benefits of an extensive meteor-monitoring program that could be carried out from the upper deck where a significant fraction of the sky would be available. These studies could range from optical spectroscopy to near-IR and mid-wave IR spectroscopy and imaging. And all from a platform that would virtually assure a cloud-free sky and low extinction.

SCIENCE STUDIES – ATMOSPHERIC

Having unfettered access to large regions of the sky from altitude would allow study of OH emissions as a function of season, latitude, geographic morphology, etc. We have models for atmospheric radiance and transmission, but providing truth data sets to validate those models could push the state of the art forward by leaps and bounds. Combined with this work, one could pursue systematic characterization of gravity waves as related to surface morphology (mountain ranges, for example) and potentially correlate their presence and strength with weather patterns.

NASA and the DoD are combining efforts to look down at the earth and characterize surface temperatures, assess crop health, detect fires, improve global climate models, and aid in weather forecasting. All of these programs depend upon our ability to calculate, sometimes with minimal additional information, the optical and thermal properties of the atmosphere. With a sensor looking up at an orbiting asset, measurements of radiance above that altitude could be made on a regular basis, and improved analysis tools developed to aid in the interpretation of the down-looking data. Some work has already been done with devices on the surface of the ocean, and in certain well-characterized desert areas, but SOFIA would allow a more wide-ranging set of conditions to be probed.

Some atmospheric phenomena are both very spatially extended and transient by nature. Aurora certainly fall into this category, and sprites and elves are very short lived, as well. Having a platform like the SOFIA upper deck available for many nights a year for many years would permit the application of evolving technologies for capture of transient events with imaging spectrographs that require little time for data acquisition and no chopping secondary on a telescope.

A simple IR spectrograph could be used to monitor the absolute level of emissions as a function of geographic location, elevation angle, volcanic dust loading, etc. Figure 1 shows the DC response of a spectrograph mounted on the NASA IRTF and looking upward. Some of the continuum emission is due to the mirrors of the telescope and the window of the dewar, but most of the prominent emissions are due to the atmosphere: CH₄ at 3.4 microns, CO₂ at 4.3 microns, H₂O in the 5-8 micron region, CH₄ at 7.7 microns, O₃ at 9.7 microns, H₂O at 12.6 microns, and CO₂ beyond about 13 microns. As was shown in the Kuiper Infrared Technology Experiment in 1986, one can learn a lot about the atmosphere, and even subvisual cirrus or stratospheric clouds, from an airborne platform looking up.

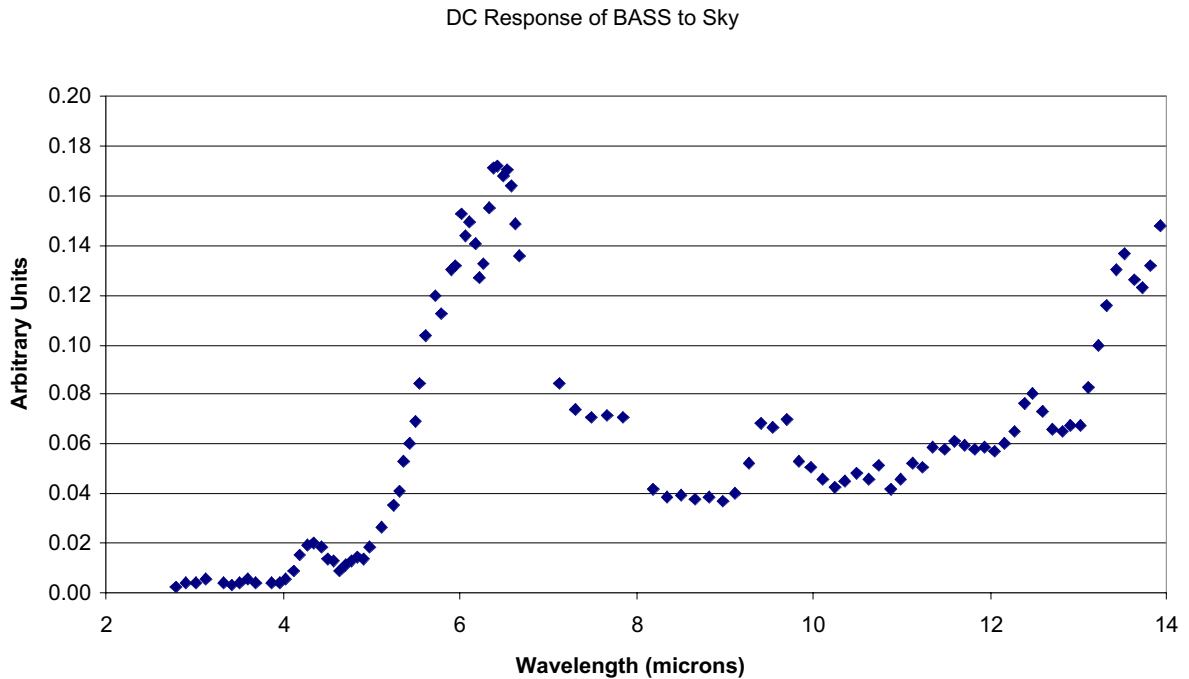


Fig. 1. DC response of the BASS instrument to the sky.

TECHNOLOGY DEVELOPMENT

The lack of an airborne observatory for a decade has cost us the educational environment where new scientists and engineers can cut their teeth on airborne technology. Other than a very limited number of facility instruments, there has simply not been a platform on which to test new ideas, and to keep the IR technology train fully loaded. The students and technically oriented people who work in the airborne environment may well go on to space-based challenges, and we are the poorer for the lack of such a program for almost a decade. The upper deck affords a new and unique opportunity for students and technicians to take new sensors and new technologies and test them in the vibration and high altitude (higher cosmic ray fluxes, for example) environment of an airborne observatory, even if they are not on the main telescope. Moreover, with the high cost and visibility of the science work being done on the main telescope, there will be little tolerance for failure or lack of productivity. Harwit has pointed out in his book on scientific discovery that two things that are needed for discovery are new tools with which to observe and the opportunity to take a chance and fail. The upper deck studies could provide that kind of arena – high risk potentially high return ideas could be developed and tested. Instead of bemoaning the loss of capability since the Apollo program, and the loss of skilled and experienced personnel to retirement, SOFIA would permit a whole new generation of ambitious, curious, capable people to come into the field without the need to wait a decade for a major space project or even major airborne project to come to fruition.

SUMMARY

In short, the upper deck offers multiple opportunities for scientific investigation, limited more by the imagination and creativity of our emerging scientists and technical personnel than by anything else. The areas of study embrace astronomy, atmospheric studies, cosmic ray studies, weather prediction, and global climate modeling. Sensors and results from the upper deck could support the analyses of data

being taken from down-looking platforms in space, as well. NASA has the opportunity to foster an environment of development creativity, while deriving more benefit from an already tremendously powerful world-class facility.

REFERENCES

- Jenniskens P., and R.W. Russell, The 2001 Leonid Multi-Instrument Aircraft Campaign - an early review. *ISAS-SP* 15, 3-15, 2003.
- Russell, R.W., G.S. Rossano, M.A. Chatelain, D.K. Lynch, T.K. Tessensohn, E. Abendroth, and D. Kim, Mid-Infrared spectroscopy of persistent Leonid trains. *Earth, Moon and Planets*, **82-83**, 439-456, 2000.

E-mail address of R. Russell: Ray.W.Russell@aero.org

Manuscript received 2004 June 21; accepted 2004 June 21.